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'Personas for lighting'. Three methods to develop personas for the indoor lighting environment

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ABSTRACT

The objective of this research is to describe and compare three different methods of generating 'persona for lighting' to envision users' behaviour within the lighting environment. 'Personas' are used to represent typical users, highlighting their needs, perspectives, and expectations to aid user-centric design approaches. The researchers looked for the most useful method of shaping 'personas for lighting' to learn about users' satisfaction with the various lighting conditions to identify their needs.

Method one of lighting persona development, was based on interviews with 87 users of five buildings of four different types: an office, a primary school, two university buildings, and a factory. The lighting conditions were observed and measured in all the buildings. As a result, 22 personas for lighting were created. In method two personas were generated based on pre-interviews, workshops on lighting and post-interviews with ten users along with the onsite lighting measurements. Later, due to the Covid-19 pandemic's lockdowns, an online survey on the visual lighting environment in home offices was carried out among 694 students and professionals from seven countries to create two more personas for lighting (method three).

All 26 'personas for lighting' were generated in relation to observed lighting conditions, based on the satisfaction, preferences and needs of the users working within variously lit indoor environments. All the tested methods can be used for nearly any type of building and room, but the resulting personas are different due to the specific limitations of the methods.

The created personas may help to identify future users' lighting preferences, needs and requirements and assist designers. However, to fully understand their impact on the lighting research practice they should be tested in real projects.

1. Introduction

Working with personas is a widespread technique in marketing, commerce, IT, design, and the social sciences that helps sales experts, designers, and researchers comprehend, and study users' behaviours, needs, goals [1] and model characters. The persona concept also helps to communicate with stakeholders and designers while evaluating design ideas [1–3], therefore it could be potentially used in lighting research and practice.

Personas, seen as descriptions of a fictitious person, fulfil a need for a holistic perspective on humans but depend on the context in which they are used in design [1,2]. Personas, as imaginary characters, enable designers to envision the users' needs, goals and wants, and to focus on user-oriented solutions. Personas are created to help designers comprehend and clarify users' goals and behaviours. They can lead to better design of the final product or space [2]. Practitioners may see personas as a beneficial tool to create a

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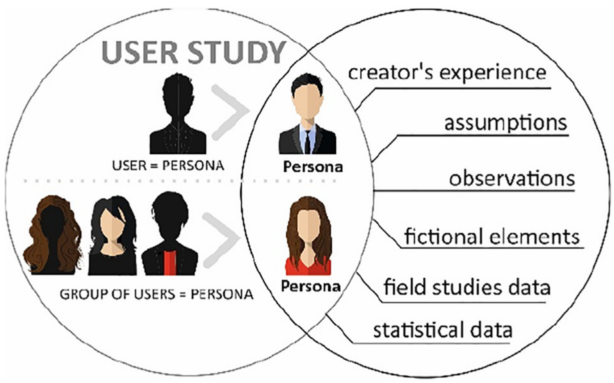


Fig. 1. Persona generation can be based on a user or a group of users by adding the creator's experience, assumptions, observations, fictional elements, field studies data, statistical data.

specific outcome and the means to better communicate with users and guide design decisions by facilitating the design process [3,4].

Personas can be based on the specific user or the group of users, or both. They can be also crated based on the creators' observations and assumptions or unique experiences (Fig. 1). Persona' characteristics can be based on users' experiences, preferences, goals, needs and typical behaviours. Cooper at al. (2007) argue that 'The key is in choosing the right individuals to design for, ones whose needs represent the needs of a larger set of key constituents, and knowing how to prioritise design elements to address the needs of the most important users without significantly inconveniencing secondary users' [5]. Personas are fictional but can be accurate and precise representations of a group of people. To add realism, a persona is usually presented in the text with a name, demographic information, and an image representing a credible user [6].

In lighting science, creating a persona could help designers and researchers understand users' perceptions of various lit spaces, their interactions with lighting, and comprehend individual lighting preferences and needs. The persona is understood as a representation of a hypothetical user, which could assist in creating user-centred lit spaces within a built environment. 'Personas for lighting' could provide many qualitative and quantitative data needed in all stages of the design process and design-focused research.

This paper describes three methods of 'persona for lighting' creation. The objective of this paper is to report and compare different methods of 'persona for lighting' creation. The discussion about different methods of creating personas may be inspiring for researchers willing to develop new personas for lighting in the future.

2. Background

The literature review on creating personal profiles and understanding user needs, choices, and behaviour demonstrated that there is a little information on creating personas in the lighting field. Most of persona profiles are used in disciplines such as IT

Table 1
Parameters influencing personas' creation and differences between theoretical and practical approaches described in literature dedicated to persona generation [3,4].

	Theory	Practice
Persona's construction and generation	Based on the user studies Based on user data Based on context analysis Based on the specific user Based on a group of users Based on mash-ups of users and fiction Based on a mix of user data and designers' experiences, observations, intuition, assumptions, preferences Based on a fictional character	The user studies User datasets The designers' experiences and assumptions The designers' decisions The statistical datasets
Persona's representation	Test, image, recording, avatar	Photo image Name Descriptive text including: • Demographic data (age, sex, location, hobbies, occupation, interests, believes, needs, wants) • Typical behaviour, activities
Persona's creation timing	Initial design stage All stages of the design	Constant updates and modifications of personas
Personas use	Design process Product development Communication	To improve understanding of users' needs To facilitate the design process To enhance the credibility of a final product To help to comprehend the users' behaviours To envision users' needs, preferences, and choices and to communicate them to different parties involved in the design process To put designers, stakeholders in the shoes of the archetypal users To empathize with the user, persona, to look through her or his eyes
Personas main types	Personas- future users of the product	Flexible personas Personas with specific needs • IT users • Children • Elderly • Patients • Users with specific cultural background Clients
Persona for the built environment	Future users Future users' behaviours – energy, lighting, equipment choices	To enhance teaching and learning experience for future designers To improve the design process To focus on user needs and preferences - users' oriented design
Persona verification or authentication	Generative dialogue, interviews Workshops	To verify the consistency of persona models

[7], product development, marketing, and architectural design: energy, green buildings usage, and user-centred design [2]. The reviewed papers indicate that there are various theoretical and practical approaches to persona construction, representation, time of creation, uses, types of environments they are created for and verification methods. The literature also shows different aims behind persona generation, from financial gain to user-oriented approaches. Some researchers along with Chang et al. and Salminen emphasise that in practice the theory is also variously understood depending on the field of study [3,4]. Table 1 offers summary of parameters influencing various persona generation approaches and methods. It also illustrates differences in theoretical and practical approaches, as described in the literature, underlining the complexities of the processes for obtaining personas [4,7,16–18,8–15].

Researchers underline different parameters influencing complexity of persona generation. Personas can be used to understand and comprehend preferences and needs (e.g., in lighting). However, preferences and specific needs (higher illumination levels) can be already embedded into the creation of the persona (e.g., lighting for the elderly) (Table 1). Overall, personas are intended as a design tool to identify and characterize the users' needs in a designed space or situation.

3. Methodology

The work on creating 'personas for lighting' was done as part of IEA SHC Task 61 Subtask A 'User perspective and requirements' activities. An international group of scientists (12 researchers) from Brazil, Italy, Japan, Norway, and Poland participated. The scientists have different educational backgrounds, such as architecture (8), urban design (2), and engineering (2), but all specialise in research on lighting within the built environment. The analysis of persona generation methods and an attempt to build a persona model lasted from September 2019 to September 2021. The work was divided into several stages resulting in three methods for creating personas for lighting (Fig. 2).

The literature reviews to understand personas' creation theory and practice were carried out in Web of Science and Scopus databases (peer-review papers from the last ten years in English) in 2019 and presented during the workshop for the whole group to discuss the best possible approaches. Then the literature review was repeated in 2021 and June 2022 with an extension to the Google Scholar database. The primary searching words included: variations of the phrases: *personas for lighting, persona for the built environment, persona generation/creation/development, persona theory, and persona practice*. Due to many ways of how to create personas but not a single information on how to do it for the lighting personas, it was decided to employ various methods.

In method 1 lighting observations and measurements were carried out in chosen buildings and followed by interviews with the users. One of the aspects considered for the development of method 1 was the lighting monitoring, which included daylight and rooms' usage recording, a use of electric lighting and an operation of shading systems (M1). Later, during the workshop dedicated to evaluation of the M1 results, it was decided to propose two other methods to allow for a deeper assessment of users' lighting behaviours and needs [18–22]. Method 2 is based on pre-interviews, a workshop on lighting basics and post-interviews with the users (M2). The third method is based on an online survey of the lighting environment in home offices with 236 professionals and 458 students from different countries (M3).

The experts evaluated and compared the methods, and as a result, 26 'personas for lighting' were created for various types of interior spaces.

3.1. Interviews with the users and monitoring of the on-site lighting conditions (method 1)

The first method (M1) is based on interviews with users of different buildings and measurements of various lighting conditions between October 2019 and March 2020. On-site interviews were performed in places where the users were working or learning or if not possible via email or phone-call. The users were enquired about their everyday working spaces and working routines. During the visit, the researchers carried out observations of the lighting conditions, shading systems, usage of the spaces, usage of electric lighting to describe the spaces via measurements and notes along with the photo documentation. Eighty-seven interviews were conducted based on M1. Next, the results and user' interviews were combined, and each of the investigators created personas based on the specific groups of users within the observed specific lighting conditions.

This method was used for developing personas for offices, schools, industry, and commercial buildings (Table 2).

A full description of all lighting measurements and the places could be found in the IEA SHC Task 61 Subtask A 'User perspective and requirements - Report A2' [23]. The work done during the investigation at a primary school in Trondheim in Norway is presented in this paper to illustrate the M1 flow better (Table 2).

3.1.1. Location

The Singsaker school in Trondheim (63° N, 10° E), Norway, was selected for the study due to its historical relevance, representativeness, and accessibility. The interviews were conducted by researchers from NTNU partly in February 2020 before the lockdown and partly in November 2020 after the school reopened.

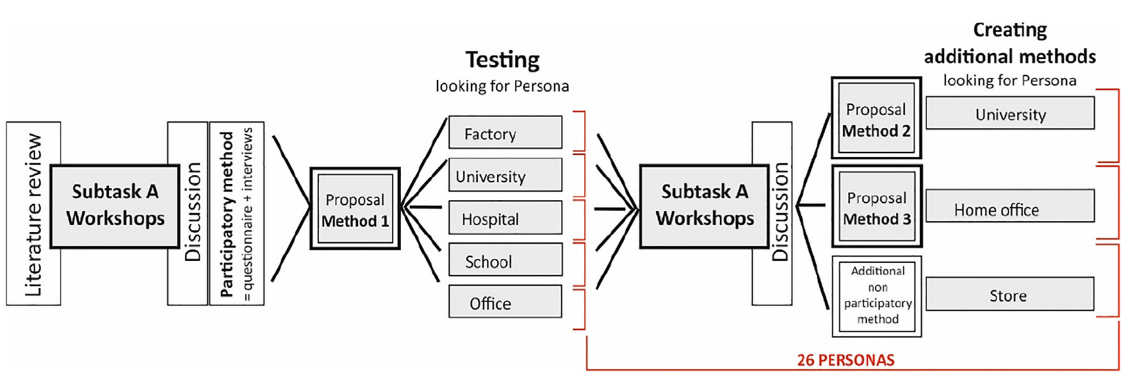


Fig. 2. Graph illustrating the elements of persona-generating workflow with three different methods and research workshops.

Table 2
Places where interviewed users worked or studied and where lighting measurements were carried out.

Function	Buildings	Location	Country	Number of interviews	Number of created personas
Office	RIAS Built Environmental Control Lab of the University of Campania Luigi Vanvitelli	41°06 N, 14°33 E	IT	16	4
School	Singsaker school in Trondheim	63° N, 10° E	NO	17	7
University	Sopot University of Applied Sciences	54°43 N, 18°56 E	PL	20	2
University	Gdansk University of Technology	54°37 N, 18°61 E	PL	12	1
Store	Co-op –medium-size store in Trondheim	63° N, 10° E	NO	8	4 (lighting measurements were not allowed during the operational hours)
Factory	Elmarco lighting factory in Gdynia	54°46 N, 18°46 E	PL	14	4
	Total			87	22

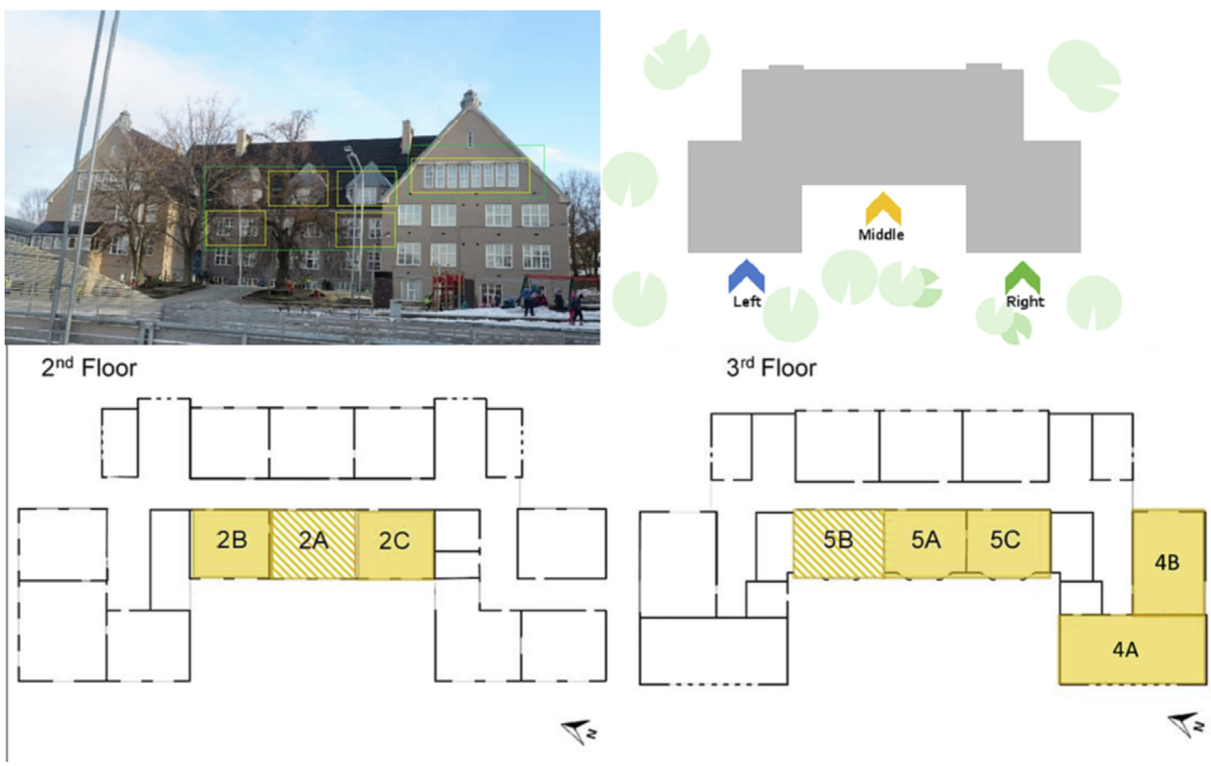


Fig. 3. Top: Image showing the west façade of the school building and locations of the investigated classes. Bottom: Shows positions of the classrooms where lighting measurements took place.

The building was designed in 1913 as a primary school building. Some restorations were done in 1942, 1958 and in 1995. The building was closed or used for other purposes during short periods of time and was reopened as a primary school for grades 1–4 in 1995. Although the building was built as a school when the education methods were very different from the current ones, it still functions well as a learning space today (Fig. 3).

3.1.2. Participants

The interviews were done with the school employees representing the following user groups: students with the assistance of a parent or teacher, teachers (assistant, younger teacher, and experienced teacher), principal and administrative personnel, and cleaning staff.

3.1.3. Procedure

The interviews were preceded by a phone call or an e-mail contact during which the researcher explained the purpose of the interview and scheduled the time. The interview was carried out following the guiding questions presented in Table 3.

At the end of the interview, the researcher could ask additional questions of a more personal character (please see the non-mandatory questions at the end of Table 3). The answers helped to create personas with a touch of reality, representing living people with some information about their living conditions, family relations and even dreams for the future. The respondents were also asked to describe their satisfaction with the lighting levels, control system, spatial distribution of light, glare, shadow, reflections, and colour using a 6-point (0–5) Likert-type scale. On the same day, the researchers carried out measurements of the indoor and outdoor lighting conditions. The researchers created one persona representing each user group. The persona was based on the gathered information from the interviews with a minimum of three persons from each category and in relation to the registered lighting conditions (Fig. 5). To guarantee conceptual and semantic equivalence of the questionnaire, the questions were

Table 3
Sequence of questions for the interview.

PERSONAL INFORMATION	• *For how long have you been working/studying here?* *Would you describe your typical day from the time that you wake up to come to school/work?* *What is a typical day at work/in general, please describe it? Start-time, end time?*
SPACE DESCRIPTION WHERE THE PERSON AND THE GROUP HE OR SHE REPRESENTS, SPENDS MOST OF THE TIME	• *How many students or colleagues do you have?* *Where do you spend most of the time in your workspace?* *Do you have a personal space/table? How often do you use it?*
ACTIVITY DESCRIPTION RELATED TO LIGHTING CONDITION IN GENERAL	• *What is your workplace like? A space with a table lamp? Ceiling lamp? Which one do you prefer, why?* *What are your typical tasks (type of visual task, fine details, colour discrimination)*
VISUAL CONDITION	• *Have you experienced some uncomfortable situations related to lighting, daylighting at your workplace? (glare, specular reflection)* *How do you feel about the lighting control system? Manual switch on–off? Automatic?* *Other opinions or concerns about lighting!*
CLOSING (NOT MANDATORY)	• *Could you tell me a little about yourself (What is your home like?/How many family members do you have?/etc.)* *And what do you do in your free time, like after school/work or at weekends?* *May I also ask what is your dream/passion?* *Do you think most of your answers are representative of the group?*

translated into the target language (Norwegian, Italian or Polish), reviewed by a second person and finally, a third person evaluated the translation result to ensure the understanding of the questions [24].

3.2. Workshops – lighting context method (method 2)

The workshop for the persona creation method was based on five steps: a pre-interview with the users (i); observations and measurements of lighting conditions (ii); training in lighting – workshops with users (iii); a post-evaluation survey with users (iv), creation of a persona (v). In this method, the users participated in the workshop's - generative sessions [25], during which they discussed the lighting conditions in their workplaces. The experts also trained them on lighting design basics. The post-workshop survey with users' purpose was to investigate how their perception and satisfaction with the observed lighting conditions had altered. The intention was also to find solutions to the noted lighting issues [25]. Therefore, the users' assessments of the lighting conditions within their workplaces were collected before and after the training workshops, emphasising possible changes. The workshops took place in June – October 2021.

3.2.1. Location

The study was conducted in the library and office rooms in the historical building of the Gdansk University of Technology, Poland (54°37 N, 18°61E). The rooms were: the main library storage, and four offices. The library workshops took place on the 6th of June 2021, under a fully overcast sky. The workshops in the offices were held on the 1st of October 2021, also under overcast sky conditions.

3.2.2. Participants

Ten participants – two librarians and eight administrative staff workers (8 women, 2 men) – participated in the workshops. The average age of the participants was 44 years old. All the office workers declared they had desks with computers and spent most of their time in front of the computer. The librarians indicated that they also had workstations with computers but spent only about half of the day in front of them. The workstations of the 10 participants were in the rooms marked in Fig. 6. The participants were divided into three groups: group 1 – office 1 with 4 people; group 2 – office 2 with 4 people; group 3 – library storage and administrative office with 2 users.

3.2.3. Procedure

The 5-step workshop method included two surveys done in a specific lighting context, the user training, and on-site measurements. The first step (i) was aimed to gather information on how the users perceive the lighting conditions around them. To achieve this goal, a survey was conducted. The questionnaire consisted of 18 open-ended, general questions. The questionnaire covered three main topics: general data (gender, age, working position, work experience, workday schedule), description of the work environment (room, workplace, lighting conditions) and behavioural patterns (tasks, tools, challenges, positive/negative aspects of work, use of light, overall expectations). In the end, 11 questions on the lighting conditions in the room (the same as used in method 1) were asked (Fig. 4). The paper questionnaire was filled out in the native language of the participants (Polish) to ensure clarity and good understanding.

The second step (ii) involved on-site observations of the users performing work activities and taking time off during work breaks (context). The observations were noted, and anonymised photos were taken. This step also included the on-site measurements of the light levels.

The third step (iii) was the workshop with basic lighting training. In this part, an expert using a presentation and professional equipment demonstrated various lighting parameters: light colour, intensity levels, and lighting distribution.

The next step (iv) was dedicated to the post-evaluation survey. The part aimed at collecting feedback from the participants on the lighting conditions after the training. In this part, the users re-evaluated the lighting conditions, re-answering the same 11 questions on the lighting conditions in the rooms (Fig. 4).

Finally, two fictional characters were created during the last step: one librarian and one office worker, based on the collected responses and discussions during the workshops (Fig. 7).

3.3. Online survey - home office & data-based personas (method 3)

The online-survey method was used to build persona based on statistical demographic and lighting data. The home office spaces were chosen in response to various types of lockdowns of public buildings in many countries to mitigate the spread of SARS-CoV-2.

3.3.1. Location

Various types of home office spaces used by students and professionals from six countries Brazil, Colombia, Denmark, Japan, Italy, and Poland, during the lockdown between December 2020 and March 2021 were investigated.

3.3.2. Participants

Most of the student-respondents were from Italy (138), Poland (110) and Brazil (93). In comparison, the professional respondents

- *Do you think most of your answers are representative of the group?*

Lighting condition at your workplace (during last week):

Satisfaction with daylight?								
[Not at all satisfied	(0	1	2	3	4	5)	Very satisfied]
Satisfaction with electric lighting?								
[Not at all satisfied	(0	1	2	3	4	5)	Very satisfied]
Satisfaction with the lighting control system, if any?								
[Not at all satisfied	(0	1	2	3	4	5)	Very satisfied]
Satisfaction with the Light Level:								
[Not at all satisfied	(0	1	2	3	4	5)	Very satisfied]
Level of Light								
[Dark	(0	1	2	3	4	5)	Bright]
Spatial distribution of Light								
[Uniform	(0	1	2	3	4	5)	Varied]
Glare								
[Invisible	(0	1	2	3	4	5)	Disturbing]
Shadows								
[Soft	(0	1	2	3	4	5)	Hard]
Reflections								
[Diffuse	(0	1	2	3	4	5)	Strong]
Colour tones of Light								
[Warm	(0	1	2	3	4	5)	Cold]
Colour (surfaces)								
[Distorted	(0	1	2	3	4	5)	Natural

Fig. 4. Eleven questions on lighting conditions given to the users in methods 1 and 2 (interviews, questionnaires). The questions were also used for M3 in the online questionnaire but with a 7-point Likert scale (e.g., "Not at all satisfied [1234567] Very satisfied" or "Dark [1234567] Bright").

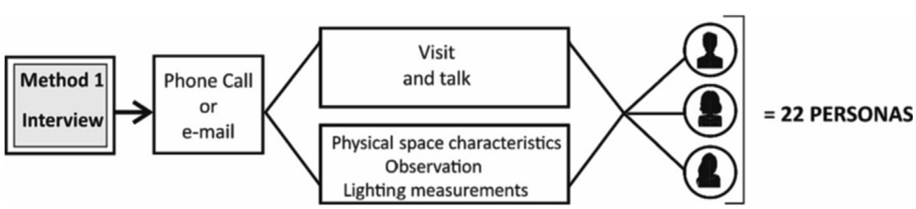


Fig. 5. Flow of method 1.

were mainly from Brazil (97) and Colombia (65). In Japan, only 61 students and none of the professionals took the survey, while in Denmark, the survey was taken by only 31 professionals. The statistical minimum number of participants was set to 50 for each country and category, but there were fewer professional respondents in Italy (15), Denmark (31) and Poland (28). Therefore, the professionals' data for Brazil and Colombia was analysed, and the students' data from all six countries was evaluated (Table 4).

To manage the unequal distribution of the types of participants, it was decided to group the data from the European countries (Italy 15, Poland 28, and Denmark 31), with 74 participants. So, the 'personas for lighting' for the professionals' category are based on the European and South American respondents. For the students' category, the persona creation process is based on the data from the respondents from Europe, Asia, and South America. Groups were created to define personas, with 50 participants per continent: South America, Europe, and Asia. In the end, two personas were created based on the results obtained from 458 students (three origin groups) and 236 professionals (two origin groups):

149 South American students 162 South American professionals
248 European students 74 European professionals
61 Asian students

3.3.3. Procedure

The online survey questions were developed by the experts group working on Subtask A of IEA Task 61 'Integrated Solutions for Daylighting and Electric Lighting', in November 2020 [22] (step i). The survey was translated into seven languages and distributed online (step ii). The participants could use a computer, smartphone, or tablet to answer the questions, which took approximately 8 min. The survey was advertised to be taken by students and professionals from Brazil, Colombia, Denmark, Japan, Italy, and Poland. An introductory section presented information, and each participant was required to voluntarily consent to the survey before taking part. The survey was composed of 6 sections containing 37 questions. The participants were also asked to take two photos with the mobile phone's camera of the home office area and the external view from the window (if present). These photos provided visual information on the various home office space layouts and characteristics. From the survey, the following information was extracted and analysed:

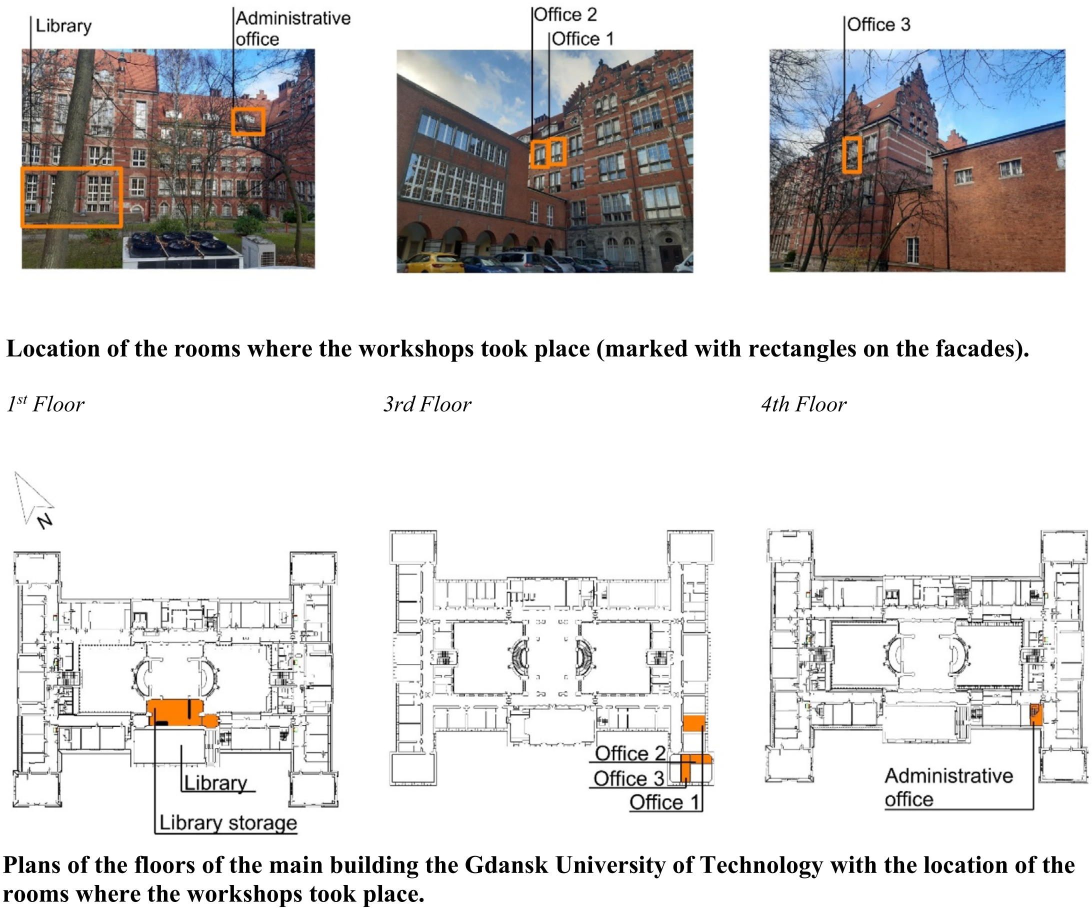


Fig. 6. Top: Location of the rooms where the workshops took place marked on the façades. Bottom: Plans of the room from the left side: 1st floor, 3rd floor, and 4th floor of the main building of the Gdansk University of Technology.

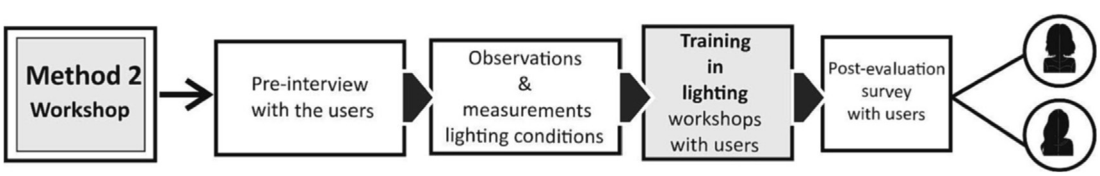


Fig. 7. Flow of method 2.

Table 4
Categories and number of ~~the~~ home-office survey participants from each country.

CONTINENT	COUNTRY	PROFESSIONALS/ COUNTRY	PROFESSIONALS/ CONTINENT	STUDENTS/ COUNTRY	STUDENTS/ CONTINENT	TOTAL/ COUNTRY	TOTAL/ CONTINENT
South America	Brazil	97	162	93	149	190	311
	Colombia	65		56		121	
Europe	Italy	15		138		153	
	Poland	28	74	110	248	138	322
	Denmark	31		–		31	
Asia	Japan	–	0	61	61	61	61
TOTAL		236	236	458	458	694	**694**

- GENERAL DATA: personal characteristics (age, sex, nationality), workday schedule, tasks, employment types and duration (section I and V),
- PREFERENCES: what influences the overall satisfaction with lighting (Sections II and III),
- PHYSICAL SPACE CHARACTERISTICS: window orientation, solar protection elements (external and internal), distance to the window, electric light fixtures (Sections IV – pictures – and VI),
- BEHAVIOUR: what are the standard actions, especially regarding electrical lighting (Sections IV – pictures – and VI),

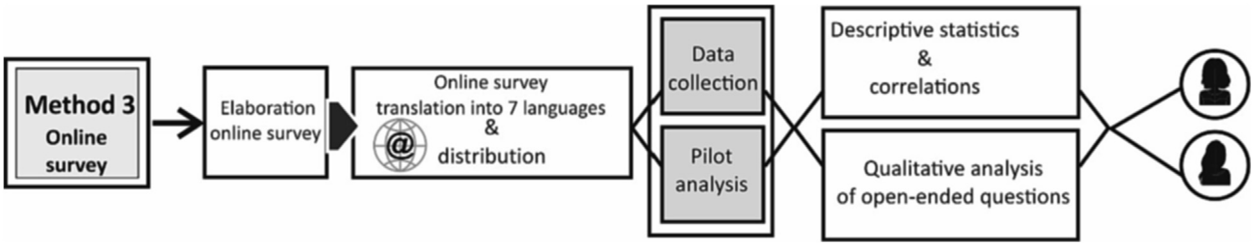


Fig. 8. Flow of method 3.

Table 5
Persona types, that were determined via the three methods.

METHOD	TYPE OF BUILDING	NO. OF PERSONAS	TYPES OF PERSONAS
M1 INTERVIEWS (LIGHTING AND THE SPACE USAGE)	office	4	3 office workers, 1cleaning worker
	school	7	2 pupils, 3 teachers, 1 administrative worker, 1 cleaning worker
	university buildings	3	1 student, 1 educator, 1 cleaning worker
	store	4	1 cashier, 1 administrative worker, 2 customers
	factory	4	2 production workers, 2 administrative workers
M2 WORKSHOPS	university building	2	1 library worker, 1 administrative worker
M3 ONLINE SURVEY	home offices	2	1 professional, 1 student
Total		26	

- ACTIONS: what the participants would like to do to improve their visual environment (open-ended question in Section VI).

After data collection and pilot analysis (step iii), descriptive statistics and correlations were performed (step iv) to create personal profiles describing attitude and behaviour regarding lighting conditions in home offices. Step (v) consisted of a qualitative, analysis of open-ended questions, with the NVivo software (QSR International 2021), aiming to understand the actions to improve the visual environment. In step (vi), general conclusions were elaborated, and the creation of the personas was performed (Fig. 8) [26,27].

4. Results

Twenty-six personas were created as the result of all the actions taken by a group of researchers using three different persona creation methods: interviews + measurements, workshops, and online survey (M1: 22, M2: 2 and M3:2) (Table 10A1 in Appendix 1). The persona types vary from pupils, students, teachers, administrative and office workers, store workers, cleaning staff members to store customers (Table 4).

4.1. Persona generations

M1 was finalised by creating 22 various persona types: 2 children, 10 women, and 10 men. This method offered only one-way interviews, and the creators (experts) were responsible for the final persona construct construction. The M1 method was partly based on studies suggesting that personas may be a tool for identifying critical issues for sustainability in the built environment [18]. A persona could even help with the communication between buildings and their users to encourage pro energy-efficient behaviours [12]. Some studies suggest that the persona construct could be seen as a user-centred design tool [18] and diagnostic tool in product requirements prioritisation in the early design stages [28]. Thus, it is pointed out that a persona could work well when used in combination with other user-centred design tools such as participatory design [18,29].

A second 'personas for lighting' generation method was suggested to address the built environment issues better. M2 resulted in the creation of two specific personas – a librarian and an office person. The experts carried out interviews during the generative workshops [25,30], and were responsible for the final generation of the persona types that were based on the group of observed users who participated in the workshops. The workshops allowed various users and persona creators (lighting experts) to gather around the table and discuss the observed and measured lighting conditions [25]. The contributors could freely express their opinions, challenge the experts, and collaborate to suggest new lighting solutions to design for the future.

In M3, the online interviews resulted in a significant amount of statistical and demographic information. The generated personas – a student and a professional – were based on a substantial group of users: 458 students and 236 professionals (Table 5). This method allowed one-way communication pathways. The experts did not directly contact the users, but got vast statistical data on the demographics, satisfaction with the lit spaces, and preferences. This method was developed to make it possible to develop personas based on datasets of a statistically significant size, which illustrate the variety and complexity of the population [6] and the lighting contexts.

4.2. Lighting conditions within the indoor built environment in 'persona for lighting' methods

The personas were created considering diverse lighting conditions in seven types of spaces (Table 4). Buildings' lit spaces conditions vary due to several factors, including locations, buildings architecture, methods of providing light within the spaces, layouts and finishes of the interiors, operational hours of the building (constant/temporal), dissimilarities between users' tasks (work in front of a computer, teaching, cleaning) and others such as lighting control systems. In order to determine the 'personas for lighting', different types of personas were created in relation to particular lighting conditions, which were registered in five buildings from buildings with heritage restrictions (M1 – school and university building) to modern constructions (M1 – office).

Seven personas out of 22 were created concerning the lighting conditions registered, measured, and simulated for the school building in Trondheim. All the classrooms in this building had large windows with access to daylight. The windows were positioned relatively high such that the students could not see the outdoor landscape from their sitting position. Their view was limited mainly to the sky. The windows were equipped with opaque and light-blocking, fabric curtains, having transmissivity (Tn) of 1.3 %. The classroom interiors were renovated a few times during the past decades. The electric lighting consisted of pendant luminaires (56 W) with fluorescent lamps for general lighting and separate fluorescent lamps for the blackboards. None of the classes that were included in this study had a dimming system, and the only control method was manual switch on/off. The teachers were the lead users, who had complete control of the electric light switching and decided how much of the glazing areas should be covered by the curtains. The lighting assessment in the school building included a series of measurements outdoors and indoors.

The measurements of the illuminances on the façades were taken for one day. The luminance levels were recorded in the classrooms for three scenarios: daylight (DL), daylight + electric lighting (DL + EL) and electric lighting only. The following measurements

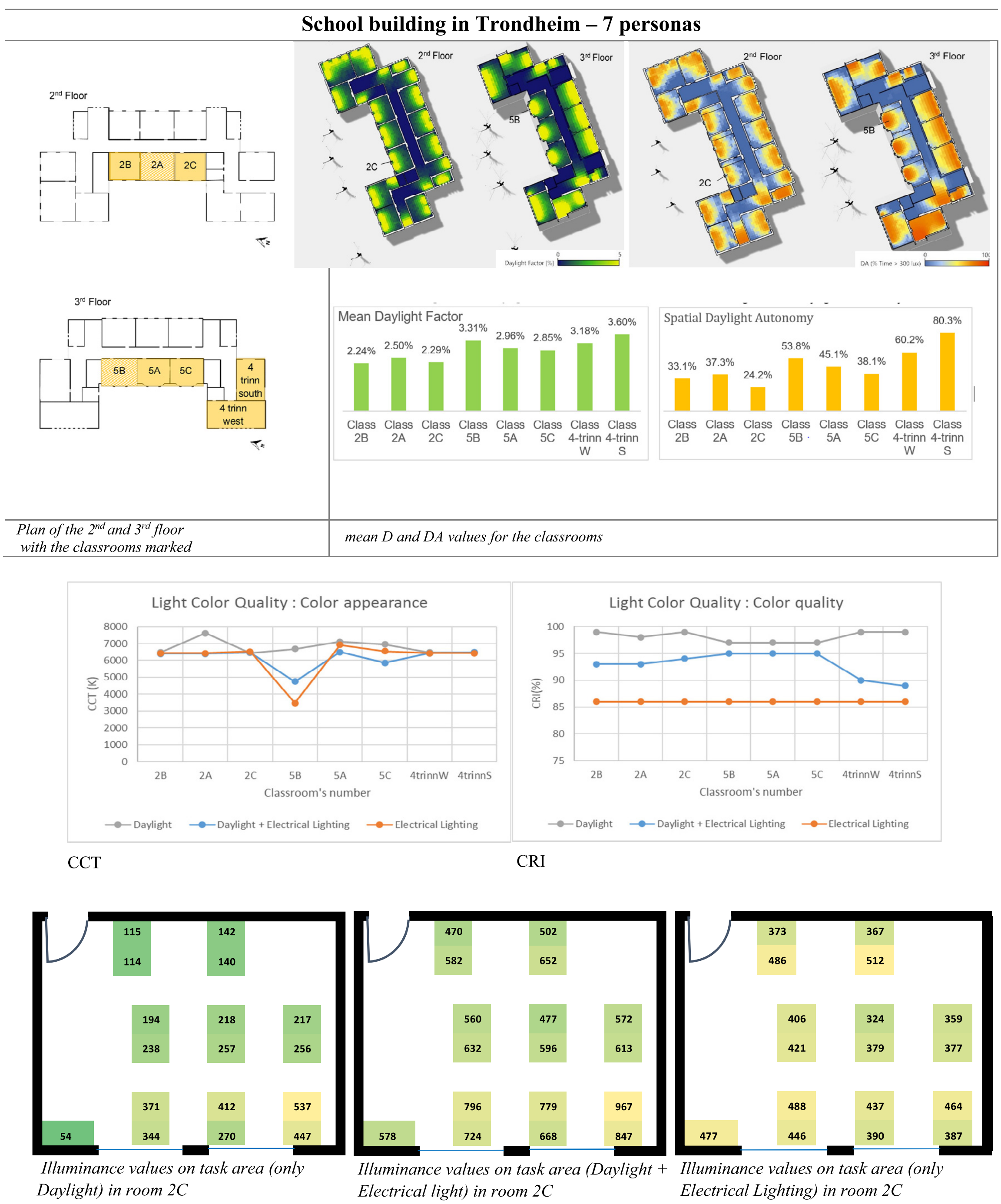


Fig. 9. HDR photographs of teachers and students (users) viewpoints in various lighting settings Daylight, Electrical Light, DL + EL in the classroom 2C [23].

Personas

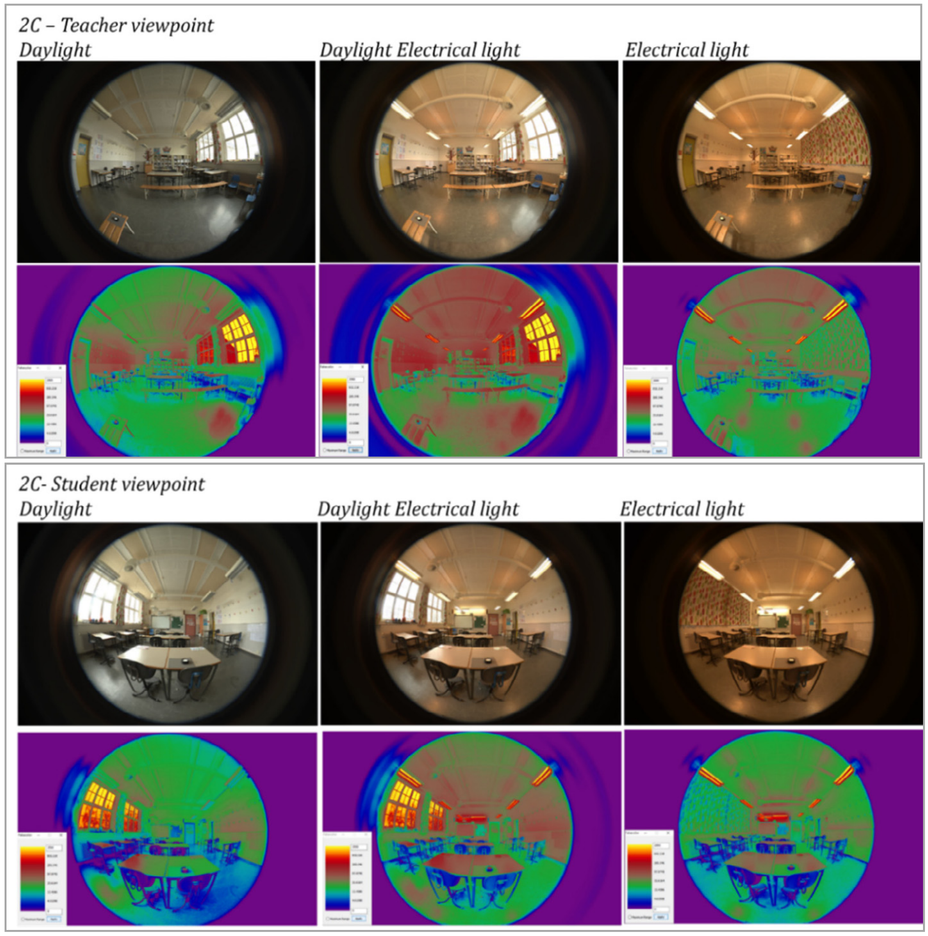


Fig. 9 (*continued*)

included: the illumination levels, spectrum power distributions (SPD), correlated colour temperature (CCT) and colour rendering index (CRI). Moreover, high dynamic range (HRD) photographs were taken from the teacher's point of view and the students' (Fig. 9). The illuminance on the working surfaces was measured with a Hagner Model EC1 lux meter, while the CCT, CRI and SPD were measured using a PR®-650 SpectraScan® Colorimeter PHOTO RESEARCH spectroradiometer. To retrieve the data, the SpectraWin2 software was used. Afterwards, the simulations of the classrooms were performed in the Rhino 3D software with the Diva-4-Rhino plug-in (Table 7).

During the workshop method (M2), two experts assessed the lighting conditions in four rooms with 10 participants to create two personas. The first room – the library – had two main spaces on the first floor: the reading room and the library storage. The library storage had four rooms: the main storage (containing the workstations), two small storage rooms and a break room. The library storage area was a workplace for participants 7 and 10. All the rooms had windows facing an enclosed courtyard. The daylight conditions for the rooms were: D 1.4 %, DA 20 %. During the measurements, the electric lighting was switched on. The electric lighting consisted of 20 hermetic linear LED luminaires (36 W, 4000 K) in the storage room and five pendant lamps in the break room. There were three types of LED light bulbs in the break room, with different parameters: two of type 1 (17 W, 2700 K), two of type 2 (25 W, 2700 K), one of type 3 (40 W, 4000 K). The lighting control systems in the rooms were manual (Table 7). The light distribution in the rooms varied depending on the place in the room (e.g., dark spaces between the bookshelves). The glare was imperceptible as the room was facing the courtyard and no direct sunlight entered the room for the whole year. The shadows were soft, and the reflections were diffuse. The surface colours in the library storage were distorted. The next rooms – three offices – were located on the third floor. Offices 1 and 2 faced southeast, and office 3 faced southwest. Office 1 had workstations for participants 2, 4, 6, 5. Participant 3 was working in office 2, and in office 3, participants 8 and 9 had their workstations. Office 1 had two large windows, office 2 had one large window, and office 3 had one medium window that was covered by curtains (Fig. 10). The daylight conditions in the rooms were: office 1: D 7.9 %, DA 100 %, office 2: D 3.3 %, DA 100 %, office 3: D 4.9 %, DA 100 %. The electric lighting in office 1 was provided by 12 pendant LED raster fittings (18 W, 4000 W) and in offices 2 and 3 by four pendant LED lamps with torus-shaped light bulbs (25 W, 2700 K). The lighting control system in all the offices was manual. The electric lighting was switched on during the measurements. In office 1, the light distribution was uniform, but glare was described as disturbing, especially during the first half of the day by the occupants. In offices 2 and 3, glare was not noticeable by the occupants. In all offices, the shadows were soft, and the reflections were diffuse. The colours of the surfaces were distorted in office 1, while in offices 2 and 3, the colours remained natural.

The last room, occupied by participant 1, was the administrative office located on the 4th floor, with one window. The daylight conditions in the room were: D 1.7 % and DA 74.7 %. The electric lighting in the room was provided by one ceiling lamp (18 W, 4000 K)

Table 6
Persona constructs' criteria used in the three creation methods.

	M1	M2	M3
Personas construction and generation	Based on the user studies Based on the specific user Based on a group of users Experts' experiences, assumptions, observations of the use of space and light conditions measurements and observations	User studies Based on a specific user Based on the workshops' participants Based on a mix of user data and the designers' experiences, observations, intuition, assumptions, preferences	User datasets Statistical datasets Based on a number of users from seven countries
Personas representation	Test, image, avatar Name Descriptive text including:demographic data (age, sex, location, hobbies, occupation, interests, beliefs, needs, wants) Typical behaviour, activities Lighting preferences	As in M1	As in M1 and M2
Personass creation timing	The initial research stage	As in M1	The initial research stage under specific restrictions – Covid 19 pandemic
Personas use	To improve understanding of users' needs To facilitate the future design process To enhance the credibility of final lighting solutions To improve communications between designers, lighting researchers, and end-users	To improve understanding of users' needs To improve existing lighting solutions To increase comprehension of lighting systems To improve communications between experts and end-users of lighting products	To improve understanding of users' needs To facilitate lighting solutions for home offices To improve communications between designers, lighting researchers, and end-users To research user preferences on lighting in specific social conditions- work from home
Personas vs their places of work and lit environments	Employees working in different types of public buildings (school, office, university, store, factory)	Employees working in specific places: library, offices within one university building	Professionals and students working from home offices with various cultural backgrounds and lighting conditions
'Persona for lighting' specific generation aim	To envision future users' behaviours – energy, lighting, equipment choices	To focus on a particular group of users within certain lit conditions	To investigate users' perception and satisfaction with lit conditions within home offices during the Covid-19 pandemic
Criteria that were used for determining the total amount of personas	Synthesis of the users' personal traits and lighting preferences Intuitive choice of the creator's/interviewer's Type of the users Work schedule Users' behaviour and remarks about lighting conditions	User's type Usage of room	User's type: students and professionals Type of visual task: working vs studying

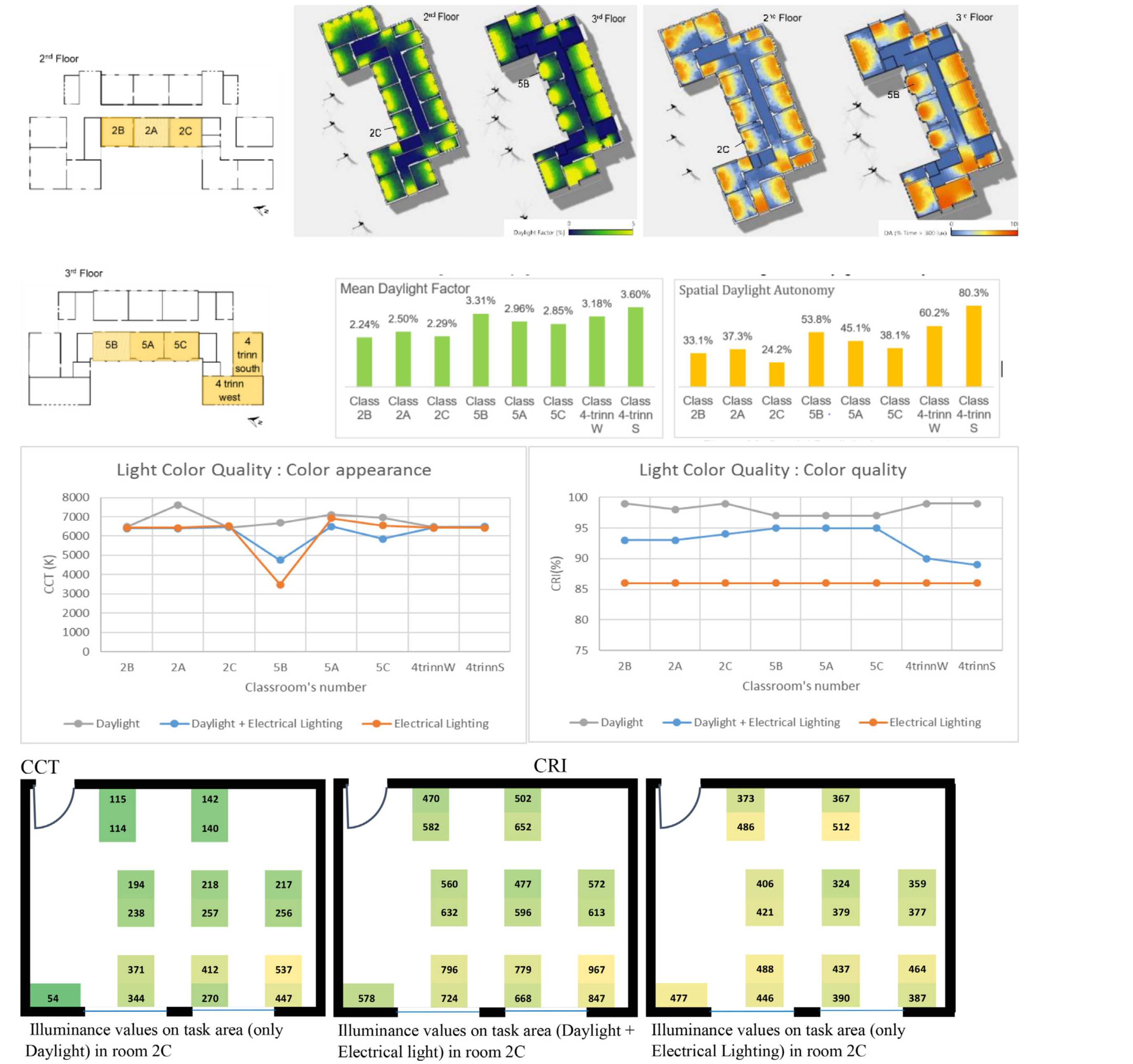
and the lighting control system was manual. During the measurements, the electric lighting was switched on. In this space, glare was imperceptible. The shadows were soft, and the reflections were diffuse; the colours of the surfaces remained natural (Table 8).

The M2 users' responses were analysed in two categories: satisfaction levels and evaluation of the lighting conditions. The lighting conditions evaluation was based on factors including lighting level, light distribution, glare, shadows, reflections, light colour, and surface colour. The responses before and after the workshops were compared. The answers given by the participants are shown in Appendix 2. After the workshop, half of the participants altered some of their responses. Two participants (participants 1 and 8) changed their evaluation of the lighting conditions – the first evaluated the conditions related to glare and shadows better after the workshop. The second (participant 8) rated their satisfaction with the daylight, electric lighting, level of light, light distribution, reflections, colour of light and surfaces higher after the training. Three other respondents (participants 3, 9 and 10) changed their answers, indicating higher and lower scores. The satisfaction with the lighting conditions was assessed as worse than the first time. At the same time, their assessments of shadows and reflections were better than before. One participant (participant 5) apprised the shadows, colour of the light and colour of the surfaces as worse the second time. Four respondents (participants 2, 4, 6 and 7) did not change their responses after the training. Notably, the changed responses were closer to the lighting results and opinions of the experts, so it can be concluded that the training resulted in a better understanding of the lighting conditions. A valid result was that the overall satisfaction responses did not change significantly. The difference between all the answers describing the participants' satisfaction with various lighting conditions before and after the workshops was minor (Fig. 11) and increased by just 0.5 % regarding satisfaction with daylight, electric lighting, control system and level of lighting (Fig. 11 and Fig. 15A2, Appendix 2).

In the M3 method, the home office lighting conditions are determined by the site locations, typology of architecture, vernacular solutions (spatial), timing and spectral characteristics of installed sources, and available daylight. The M3 formula, based on the subjective responses of the users describing their lit home office environment, required them to take two photos of the view outside the window and working station conditions. These photos taken by the users illustrate the various light conditions within the home offices in five countries (Fig. 12). Reading and writing on digital media were the most common visual task (average 29.7 %), followed by participation in digital meetings or classes (average 28.2 %). Most of the users preferred daylight or appreciate natural illumination for their home offices (Fig. 13). Compared to the students, most of the professionals had a whole room for the home office (51.85 % of S. Americans and 42.59 % of Europeans), which indicates better conditions. The predominant window orientations were South/Southeast/Southwest (average 31.2 %) and North/Northeast/Northwest (average 30.5 %). The distance from the table to the window among both professionals and students was between 1 m and 2 m (43.4 %). Internal shading devices seemed to be a universal solution, and ceiling lamps were the most wide-

Table 7
Lighting measurements and simulation results: mean D and DA in the school building in Trondheim.

School building in Trondheim – 7 personas



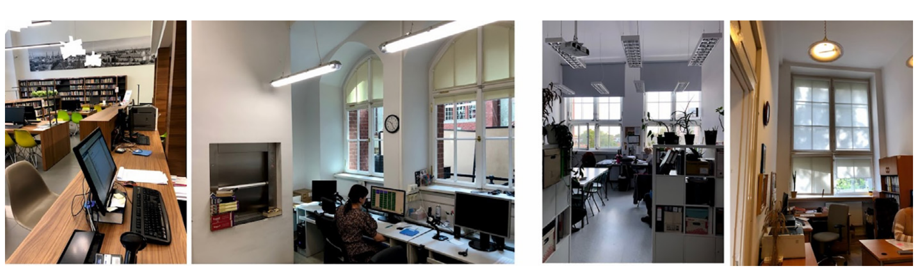
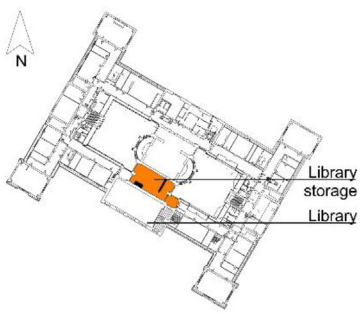


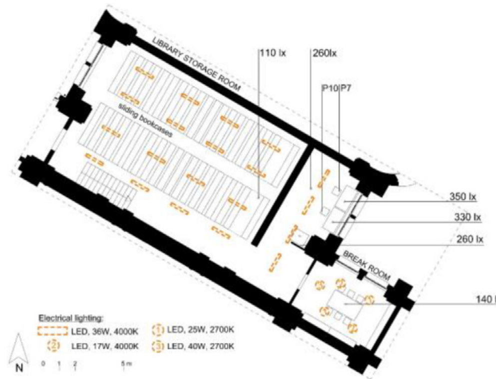
Fig. 10. M2 spaces: a reading room (1st floor), library storage (1st floor), office 1 (3rd floor), office 2 (3rd floor).

Table 8
Daylight factor and daylight autonomy simulated in Climate Studio 1.1 for the investigated spaces during M2 within the university building.

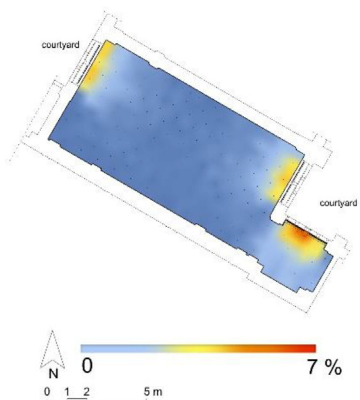
LIBRARY STORAGE

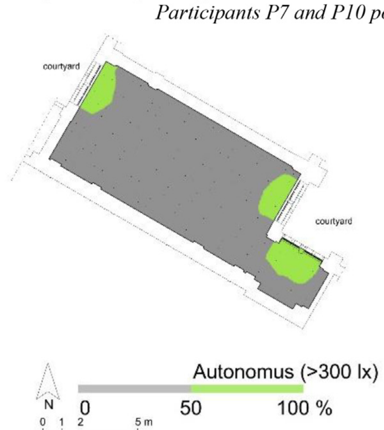
Location in the building –1st Floor





Plan of the library storage with illuminance values measured on the desks levels. Participants P7 and P10 positions marked



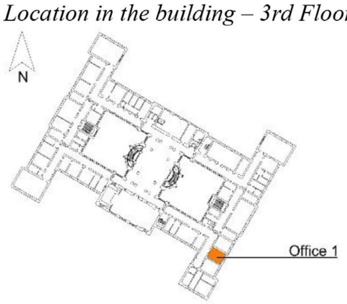


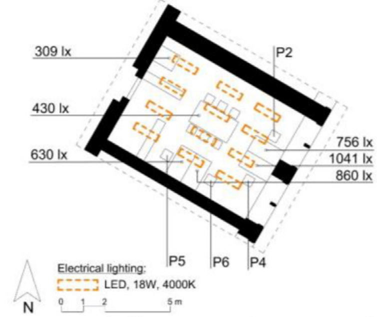
D (Daylight Factor) =1%

DA (Daylight Autonomy 300 lux; 50% occupancy time) = 12%

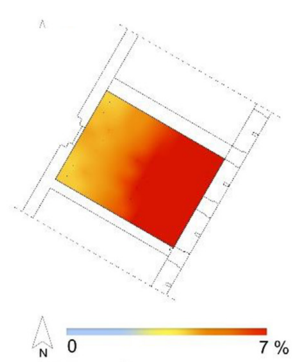
OFFICE 1

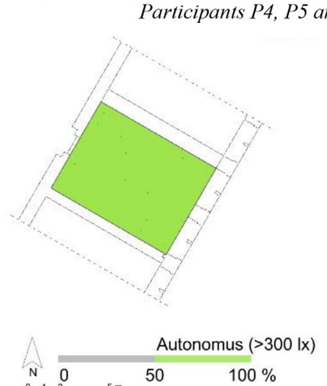
Location in the building – 3rd Floor





Plan of the library storage with illuminance values measured on the desks levels. Participants P4, P5 and P6 positions marked





D (Daylight Factor) = 7.9%

DA (Daylight Autonomy 300 lux; 50% occupancy time) = 100%

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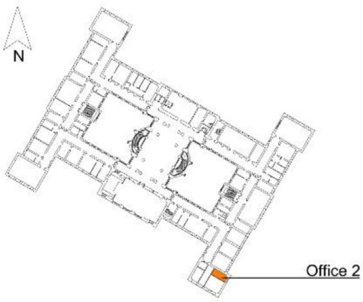
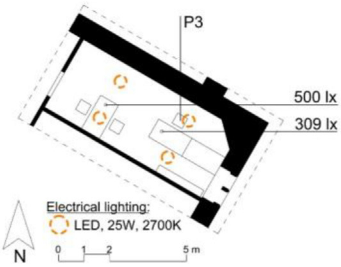
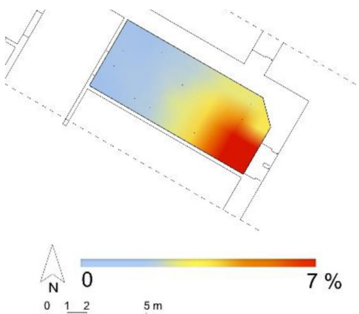
OFFICE 2

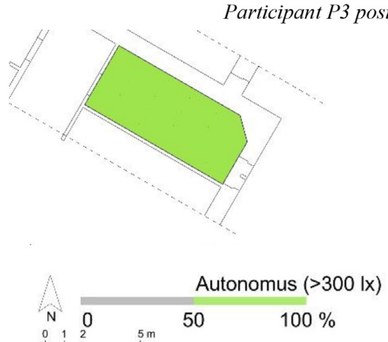
Personas





Plan of the library storage with illuminance values measured on the desks levels. Participant P3 position marked



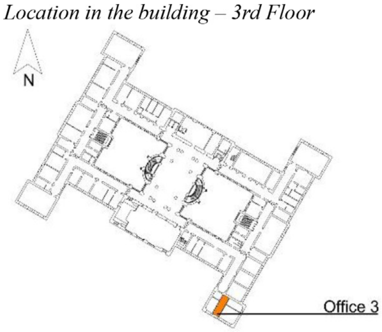


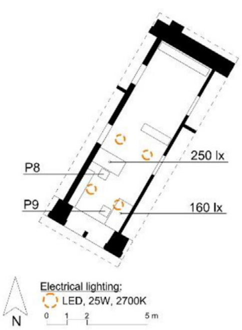
D (Daylight Factor) = 3.3 %

DA (Daylight Autonomy 300 lux; 50% occupancy time) = 100%

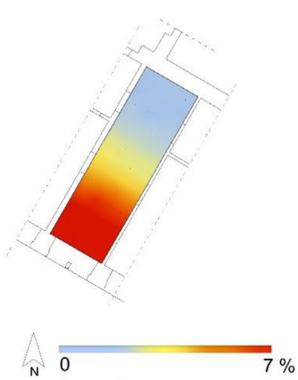
OFFICE 3

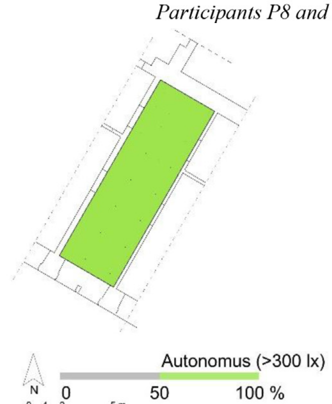
Location in the building – 3rd Floor





Plan of the library storage with illuminance values marked on the desks levels. Participants P8 and P9 positions marked

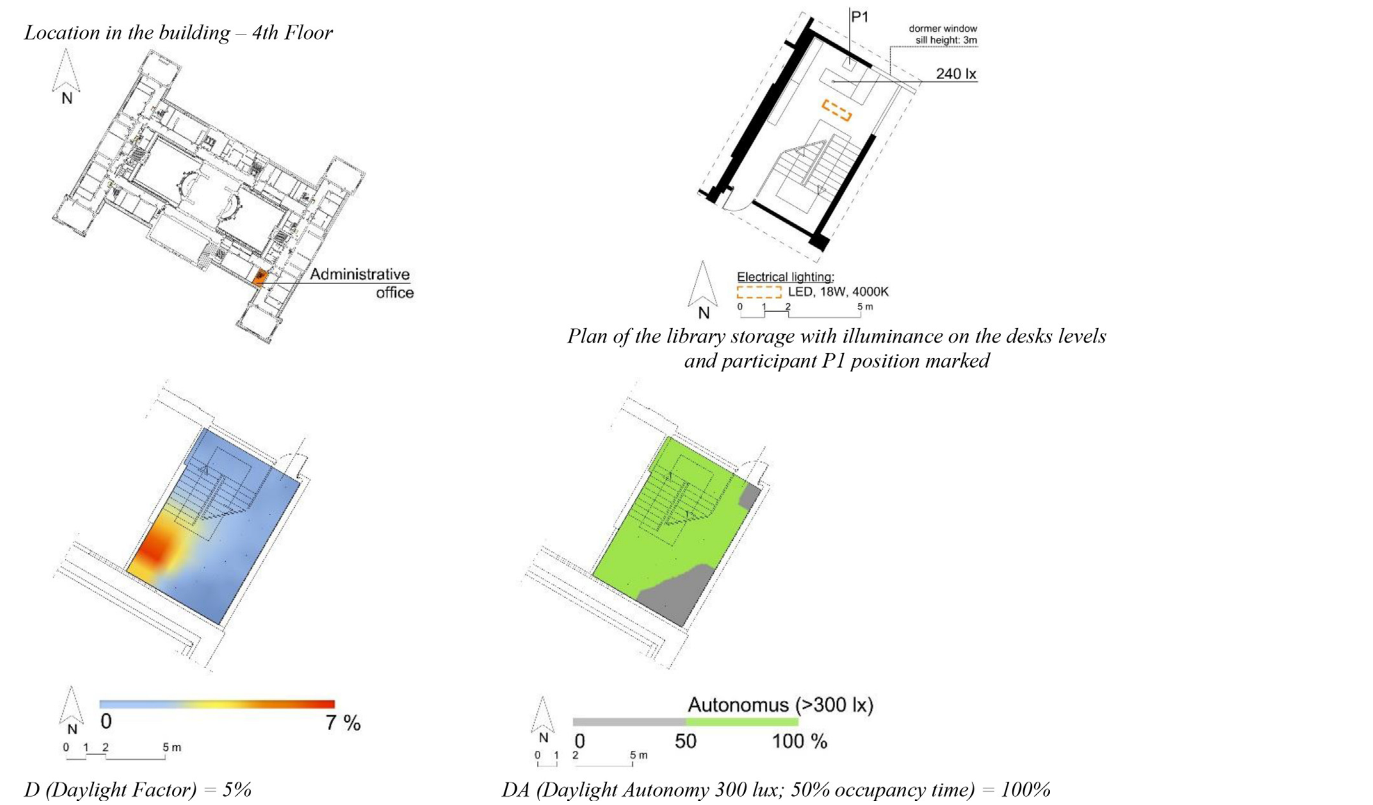




D (Daylight Factor) = 5%

DA (Daylight Autonomy 300 lux; 50% occupancy time) = 100,0%

ADMINISTRATIVE OFFICE



spread electric lighting solution in all countries. The users perceived the overall lighting within the home offices as bright with few occurrences of disturbing glare, light distribution neither uniform nor varied with soft shadows and diffuse reflections, and natural colours (Fig. 12). Overall, the colour of the surfaces appeared to be somewhat natural for all participants, as a light colour was perceived as neutral, which could be partially explained by the survey being taken mainly during the daytime. In general, 47.62 % of all occupants were satisfied or very satisfied with the daylight and a little bit less satisfied (34.94 %) with the view from the window (Fig. 14). A high percentage of occupants (75.7 %) were satisfied with the visual environment, and a similar percentage wanted to continue to work from their home offices after the pandemic. The need to change the electric lighting was mentioned most often in general terms and specifically with regard to the colour temperature and quantity of light. The need to change the daylighting was most often mentioned concerning the position of the table to the window. Climate and architecture variances could explain differences in interior design styles, lighting fittings, and lighting usage. Due to the vast data gathered during the home office surveys, a detailed descriptive analysis, including the occupants' perception and satisfaction with the lighting, is described in two separate [26,27].

5. Discussion: comparison of the 'persona for lighting' methods

As the literature review on persona creation demonstrated many methods can be employed to determine personas, depending on the discipline and the aim of the process. Some researchers are using field studies [31] with direct interviews, others customer segment isolation using online customer demographic data such as gender, age, location and behavioural data learnt by studying customer interactions with online content [7,8]. Studies show that with access to big data, quantitative statistics have changed the generation of personas [4,6]. Adlin and Pruitt argue that personas should be based on data and case studies [32] but as Nielsen [1,33] describes, the relationship between data and fiction varies from case to case and from method to method. Sometimes, fictional elements are merged with statistical data to promote empathy [5], and sometimes the persona is created with no relation to actual data [34,35]. Therefore, different criteria were used for determining the total amount of personas in each method (please refer to Table 6 and Table 13A).

The methods of 'persona for lighting' generation proved to be rather time-consuming, which demanded multidisciplinary knowledge from psychology [4,29], sociology, lighting engineering, architecture and others.

M1, although laborious and tools-demanding, proved to be productive, as it resulted in 22 different 'personas for lighting' compared to the outcomes of M2 and M3, during which only two personas per method were generated. Such differences were partly caused by the types of tools and methods chosen, but also by the fact that the created 'personas for lighting' were the results of research investigation, not a part of a design process (Table 11A3 Appendix 3).

None of the methods resulted in contradictory persona models. Thus, it was impossible to compare the 'quality' of the personas regarding their use for lighting research and design. This area needs to be further studied.

All the generated 'personas for lighting' have lighting-related elements included in their text descriptions, as all of them were created based on users working or studying within registered or described lighting conditions.

However, during M1 and M2, it was possible to observe the users' behaviour towards lighting (sometimes subconscious behaviour) not only via subjective responses to the questions but also via workshops [30] and the onsite observations and measure-

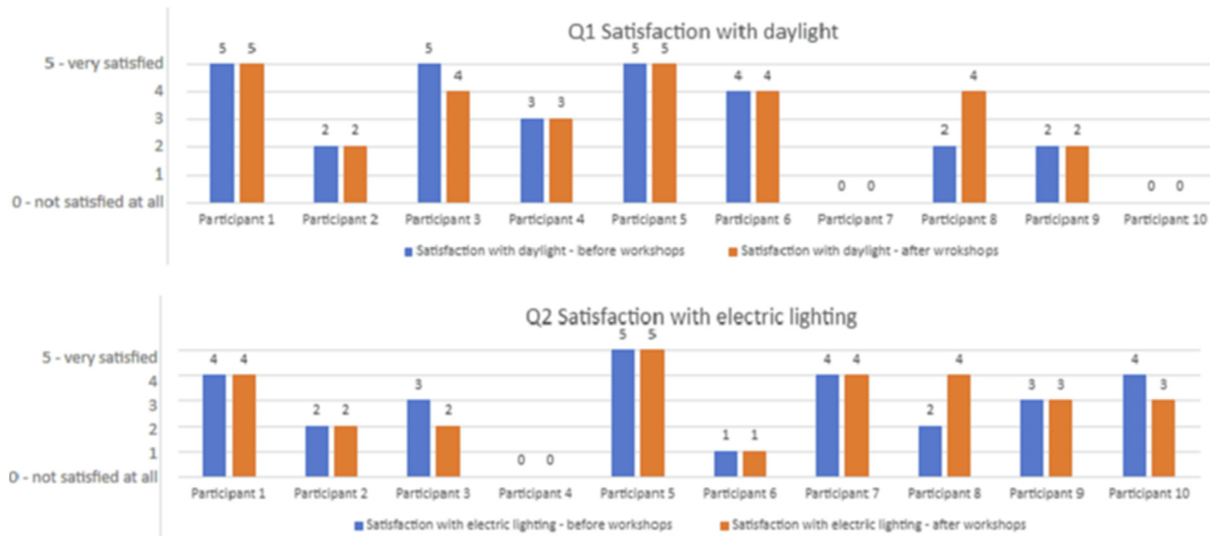


Fig. 11. Differences between participants' satisfaction with daylight and electric lighting before (blue) and after (red) the workshop. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

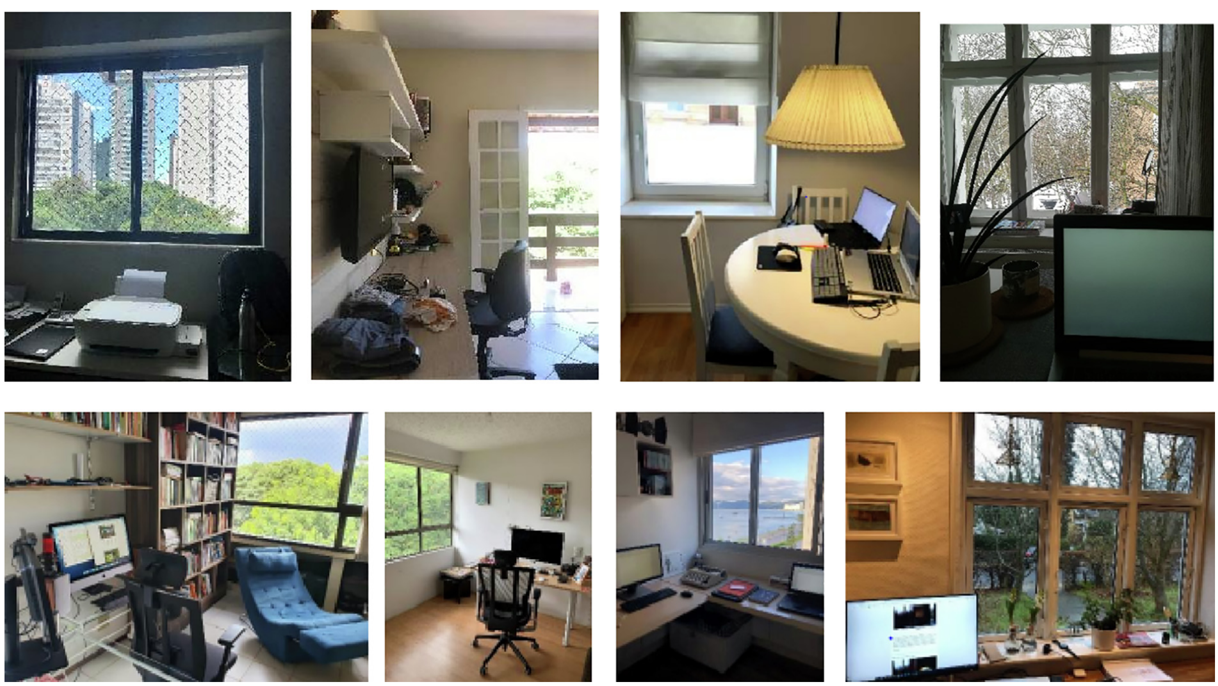


Fig. 12. M3: Photos taken by users to illustrate lighting conditions in their home offices.

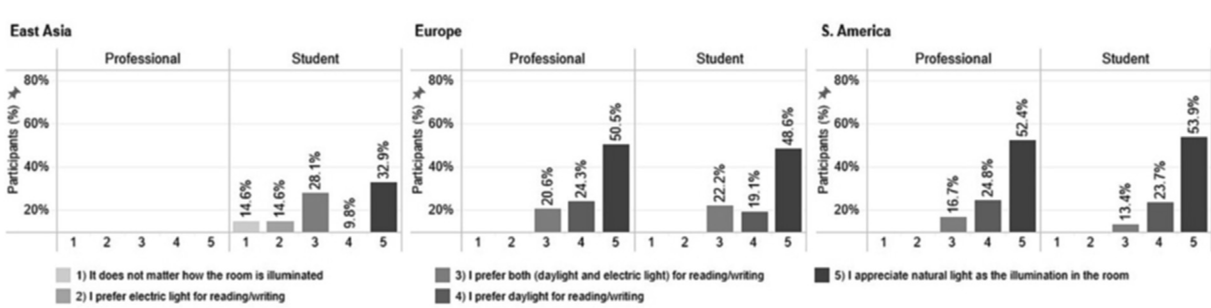


Fig. 13. M3: preferred light source in the home office.

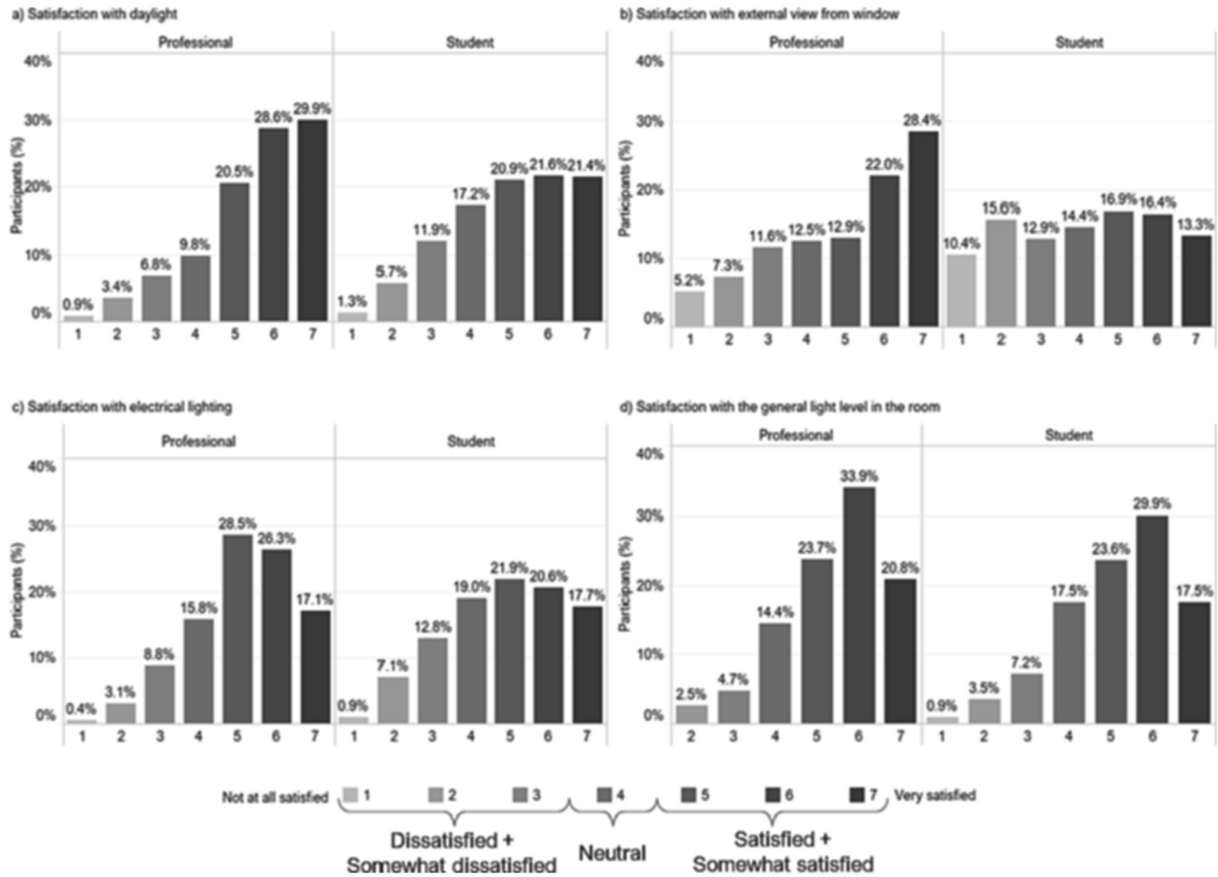


Fig. 14. Satisfaction with daylight, electric light, external view from the window and general light level in the room among respondents – students and professionals – of the online survey on the home office lilt environment.

ments within the chosen indoor lighting environments [20]. The face-to-face interviews formula included an evaluation of the visual environment on a Likert scale in parallel with lighting measurements. This process enabled the creator to identify some light-specific problems and include them in the personas' descriptions.

During M1 in the primary school, it was found that the children sitting by the door wall may perceive specular reflections (of windows) on the blackboard more often than the others. This observation was included while building the Alexander persona. Another observation was that the most comfortable sitting place (for vision) was close to the windows and the blackboard. This was because the main direction of the view for the students was towards the blackboard (Fig. 9). Visual disturbances caused by daylight from the windows and electric lighting from the suspended lighting fixtures were not present in the visual field, and there were no specular reflections on the blackboard. These observations were included in the Isabella persona, who had slightly impaired vision and needed to use a most visually comfortable place.

Even in a store where lighting measurements could not be taken during operating hours, the problem identified as glare from low sunlight was included in the persona's generation. M1 and M2 tools such as face-to-face interviews, 6-point (0–5) Likert-type evaluation of lighting conditions (questionnaires), and on-site observations of lit spaces helped to distinguish the lighting-related challenges (Fig. 15).

The first and second methods required unlimited access to the building for the users and the investigators, which was not always possible, especially during pandemic lockdowns (Fig. 16). In M3, all the respondents had unrestricted access to their spaces, and the investigators did not require access. M1 and M2 were more demanding tools than M3, which only required the questionnaire and statistical software (Fig. 17).

All three methods require the users' cooperation and willingness to take part in the study (Fig. 17).

The number of users required to determine the personas in M1 and M2 could differ from a few to several, depending on the creator's choice (Fig. 16).

The online survey (7-point Likert-type) in M3 produced data from several different ages of users from various cultures and socio-economic groups working under different lighting conditions. It demanded answers from many participants to fulfil the proposed statistical demands; in this case, 50 users from each subcategory. As M3 generated vast statistical data, many more personas could be generated depending on various factors: location, type of the building, demographic information on the users, and others. The advantage of this method was the possibility of incorporating cultural differences into the 'personas for lighting', which was impossible in M1 and M2. The lack of measurements and observations of the lighting conditions and relying on the participants' photos and answers concerning their perception of the lighting was a limitation of M3. Some of the answers concerning the lighting conditions were contradictory (a lack of shading devices or system, but the photos showed curtains). The other limitations of M3 were related to the type of questions asked. It was noted that more questions should be added to enquire about the appreciation

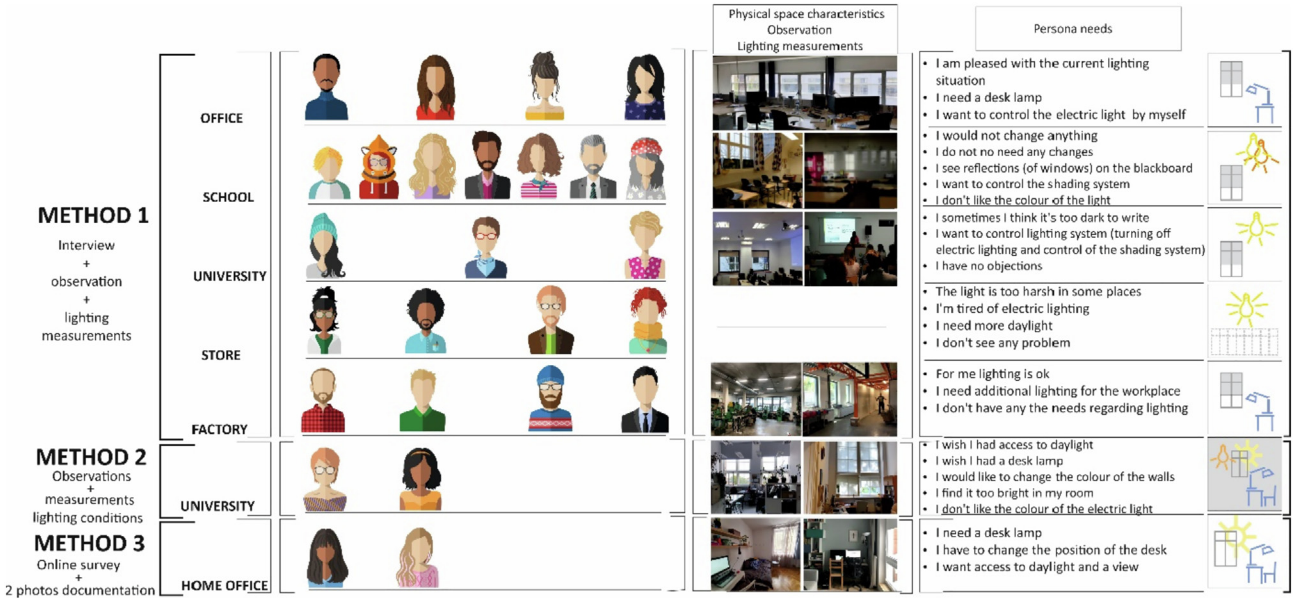


Fig. 15. Generated personas lighting needs in the three investigated methods.

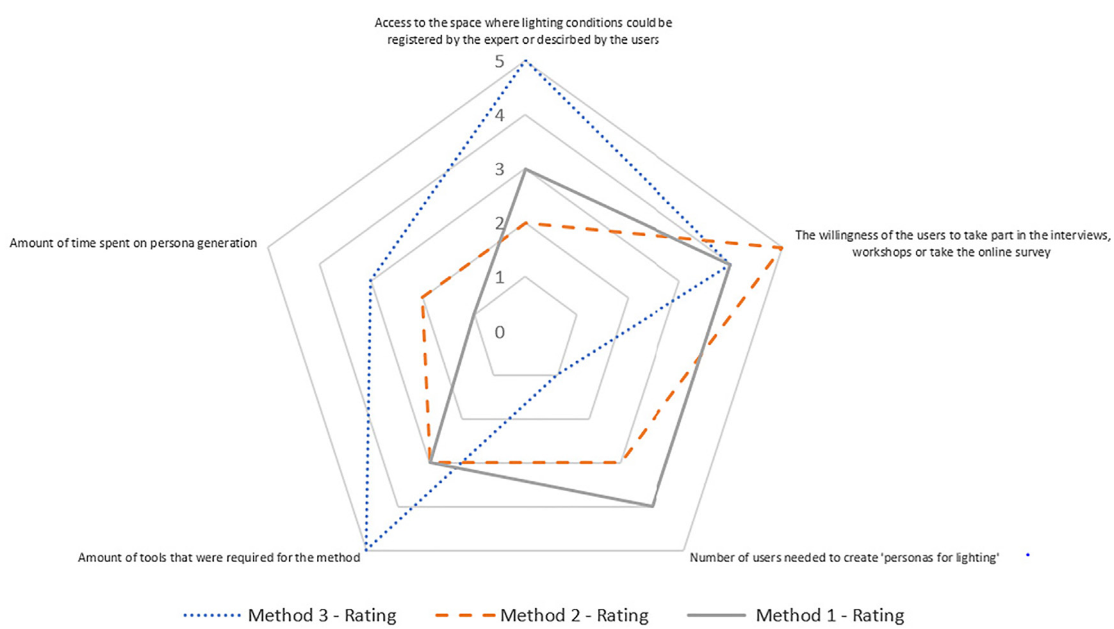


Fig. 16. Chart summarising chosen aspects of the three methods, which were discussed while generating the personas.

of the existing lighting, perception, preferences, satisfaction and needs for lighting, and the wording should be carefully chosen (Table 9).

As M1 and M2 allowed lighting measurements and face-to-face contact at the location, it resulted in better needs identification for the personas in relation to specific lighting conditions (Fig. 16).

6. Conclusions

There are many methods to construct personas. However, the literature review did not produce any results on the recommended methods to generate personas for lighting. The methods described in this paper propose three different approaches based on interviews with lighting users and monitoring and measurements of lighting conditions (M1), workshops with users and measurements of lighting conditions (M2), and an online survey with users with photo documentation taken by the users (M3). The 26 personas created as a result of these three approaches are all related to various registered lighting conditions. The users on whom the personas are based all worked within specific lit environments; their preferences, satisfaction and needs were investigated through interviews, workshops or the online survey. The registered or described lighting conditions include combinations of daylight and available electric lighting within the investigated interior spaces. The spaces were located in various types of buildings: schools, universities, factories, office spaces and home offices. These spaces offered diversified lighting conditions based on different lighting provision systems.

The interview method (M1 and M2) enables good communication with the user and the opportunity to ask direct and personal

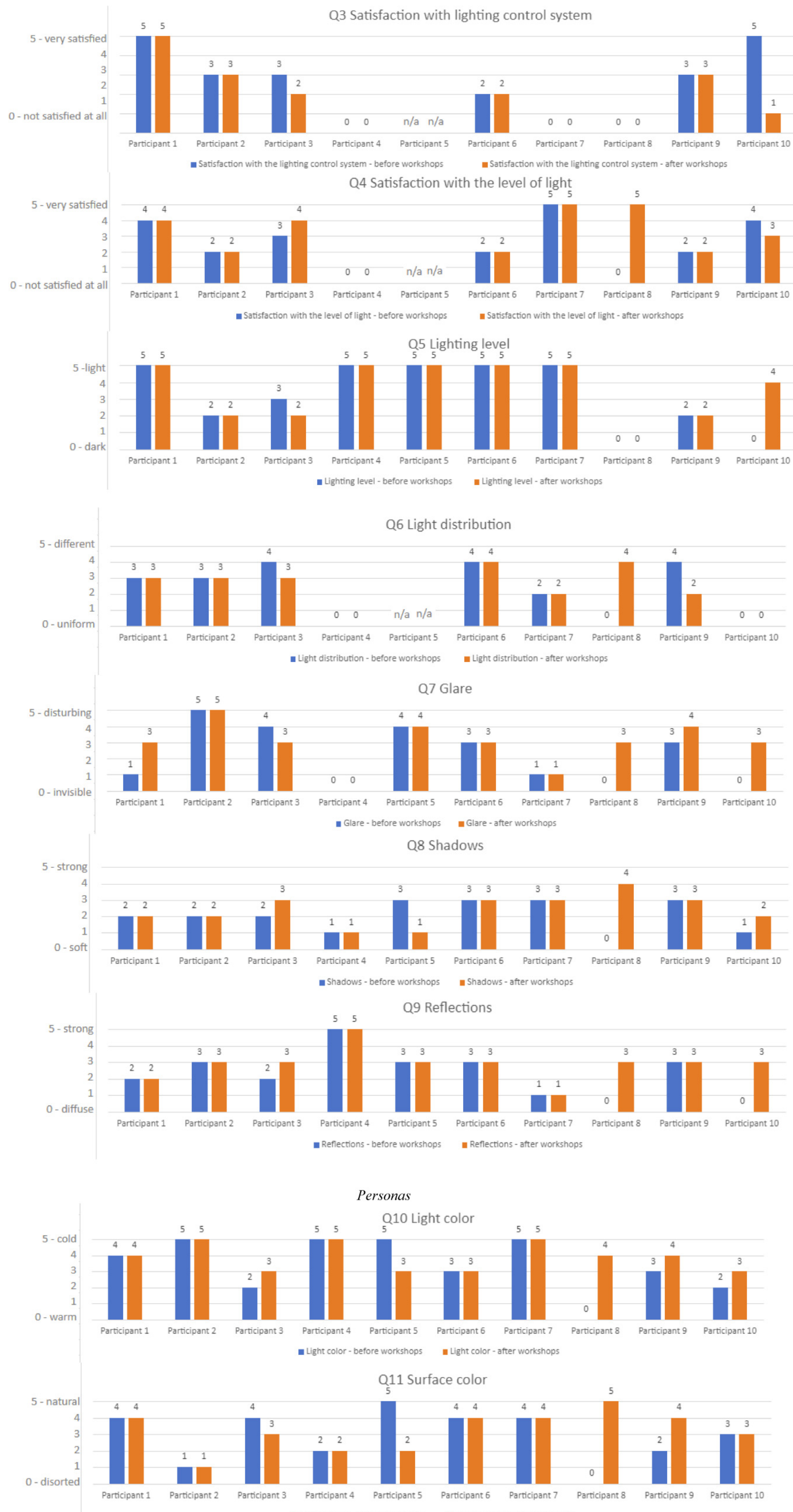


Fig. 17. Comparison of the before and after workshops users' levels of satisfaction (scale 0- not satisfied at all, to 5- very satisfied) with, the lighting control system and the level of light and before and after evaluation of chosen lighting conditions. Detailed questions are presented on the Fig. 4.

Table 9
'Must have' elements, limitations, and recommendations for future use of the chosen methods.

Method	Monitoring protocol 'must have' elements	Limitations	Recommendations for future use
M1	Face-to-face interview Lighting measurements Photo documentation	Lack of cultural diversity One-way communication pathway	Intended to illustrate more specific light-related problems within different types of spaces. More questions on lighting need to be required
M2	Face-to-face interview Lighting assessments Workshop Photo documentation	Lack of cultural diversity Workshop dynamics could be misleading – agreement with the group Selected specific indoor lighting conditions	The pre-interview should be individual and face-to-face More enquiries on personal lighting needs and preferred solutions Help form environmental psychologists should be strongly recommended The lighting assessments should be done according to one scenario not many
M3	Online survey Some form of lighting conditions verification – photos taken by the users	Lack of on-site lighting measurements Lack of personal information in the context of the users' lighting preferences, satisfaction or needs No possibility to communicate with the users	More questions on users' needs and lighting preferences Careful choice of wording, examples of various light characteristics are needed Intended for international studies

questions on preferences and needs, lighting habits, and the history of lighting exposure. The presence of the interviewer and persona creator within a lighting context described by a user enables them to observe, measure and appraise the discussed lighting levels. The disadvantages of interviews and lighting monitoring methods are the time allocated to interview the individual users and assess the particular lighting conditions. The workshop method (M2) enables two-way communication between the user and the researcher. It enables discussion between the users and collects many subjective lighting assessments. The workshop formula provides the opportunity to demonstrate alternative lighting solutions, and practice control of the lighting. The participants can be guided, monitored, or taught by the interviewer and researcher. Although this method is less time-consuming than individual interviews, its disadvantages are the different dynamics of groups and the possibility that the demonstrations and data measurements can temporarily influence the users' opinions and responses. The online survey method (M3) makes a statistical analysis of a large data set possible. Despite the photo provided by the respondents, the persona-creator does not have the opportunity to observe lighting within hundreds of home office lighting setups. In this method, less time and equipment engagement are required. This method allows the persona's construct to be based on statistical data, but actual lighting characteristics are never registered.

All three of the methods for developing personas can be used for nearly any type of building and room, but the resulting personas will be different due to the specific limitations of the methods. For instance, personas developed by M3 will be stricter and formal, as the method does not allow more personal questions. On the other hand, personas developed by M3 may represent the group more precisely (Table 9). The descriptions of persons from M1 and M2 could contain more specific light-related problems. Thus, the chosen method should be based on the time, tools, and human resources available.

To conclude, what the 'personas for lighting' look like at the end of the process depends mainly on:

- which method of developing the personas was used (a form of communication with the users),
- the lighting conditions in the room (light-specific issues included, field studies data, statistical data),
- the researcher(s)/creator(s) experience, assumptions, and observations.

All 'personas for lighting' in this study were determined to learn about users' satisfaction with the variously lit conditions and to identify their needs to help researchers and designers. The created lighting personas could help point out future users' lighting preferences and requirements, but they should be tested in real projects. As for a reference for future 'personas for lighting' studies, more emphasis could be put on tools that enquire into the acceptability of lighting conditions, diverse users' preferences, and lighting needs within the specified indoor environments.

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Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

[1] L. Nielsen, Editorial: Design personas -new ways, new contexts, Pers. Stud. 4 (2) (2018) 2007–2010.
[2] T.D.O. Tvedebrink, A. Jelic, Getting under their skin: Applying personas and scenarios with body-environment research for improved understanding of users' perspective in architectural design, Pers. Stud. 4 (2) (2018) pp.

[3] J. Salminen, B.J. Jansen, S. Jung, Are personas done? Evaluating the usefulness of personas in the age of online analytics, Pers. Stud. 4 (2) (2018) 47–65.
[4] Y.N. Chang, Y.K. Lim, E. Stolterman, Personas: From theory to practices, ACM Int. Conf. Proc. Series 358 (2008) 439–442.
[5] A. Cooper, R. Reimann, D. Cronin, *About Face 3: The Essentials of Interaction Design*, 3rd, Wiley Publishing Inc, 2007.
[6] J. McGinn, N. Kotamraju, Data-driven persona development, in: *Conference on Human Factors in Computing Systems - Proceedings*, 2008, pp. 1521–1524.
[7] J. Salminen et al., From 2,772 segments to five personas: Summarizing a diverse online audience by generating culturally adapted personas, First Monday 23 (6) (2018) pp.
[8] J. An, H. Kwak, S. Jung, J. Salminen, B.J. Jansen, Customer segmentation using online platforms: Isolating behavioral and demographic segments for persona creation via aggregated user data, Soc. Netw. Anal. Min. 8 (54) (2018) pp.
[9] R. Marshall et al., Design and evaluation: End users, user datasets and personas, Appl. Ergon. 46 (2015) 311–317.
[10] J. An, H. Kwak, S. Jung, J. Salminen, M. Admad, B. Jansen, Imaginary people representing real numbers: Generating personas from online social media data, ACM Trans. Web 12 (4) (2018) pp.
[11] L. Nielsen, K. S. Hansen, Personas is applicable - A study on the use of personas in Denmark, in: *Conference on Human Factors in Computing Systems - Proceedings*, 2014, pp. 1665–1674.
[12] S. Khashe, G. Lucas, B. Becerik-Gerber, J. Gratch, Buildings with persona: Towards effective building-occupant communication, Comput. Human Behav. 75 (2017) 607–618.
[13] L.G. Bakker, E.C.M. Hoes-van Oeffelen, R.C.G.M. Loonen, J.L.M. Hensen, User satisfaction and interaction with automated dynamic facades: A pilot study, Build. Environ. 78 (2014) 44–52.
[14] B. Ferreira, W. Silva, E. Oliveira, T. Conte, Designing personas with empathy map, in: *Proceedings of the International Conference on Software Engineering and Knowledge Engineering, SEKE*, 2015, pp. 501–505.
[15] A.N. Antle, Child-personas: fact or fiction? Child-based personas: need, ability and experience, Cogn. Technol. Work 10 (2008) 155–166.
[16] J. Salminen *et al.*, Generating cultural personas from social data: A perspective of middle eastern users, in: *Proceedings - 5th International Conference on Future Internet of Things and Cloud Workshops, W-FiCloud 2017*, 2017, pp. 120–125.
[17] J. Salminen, J. An, L. Nielsen, H. Kwak, S. G. Jung, B. J. Jansen, "Is more better?": Impact of multiple photos on perception of persona profiles, in: *Conf. Hum. Factors Comput. Syst. - Proc.*, vol. 2018-April, no. May, 2018.
[18] E. Siddall et al., Personas as a user-centred design tool for the built environment, Proc. Inst. Civ. Eng. Eng. Sustain. 164 (1) (2011) 59–69.
[19] J. Rotmans, Integrative assessment in environmental studies, Int. Encycl. Soc. Behav. Sci. (2001) 7596–7600.
[20] S. Chraibi, T. Lashina, P. Shrubsole, M. Aries, E. van Loenen, A. Rosemann, Satisfying light conditions: A field study on perception of consensus light in Dutch open office environments, Build. Environ. 105 (2016) 116–127.
[21] D. Georgieva, K. M. Schledermann, S. Maria, L. Nielsen, E. K. Hansen, Designing User Centred Intelligent Classroom Lighting, in: *Designing User Centred Intelligent Classroom Lighting. In: Brooks A., Brooks E., Vidakis N. (eds) Interactivity, Game Creation, Design, Learning, and Innovation. ArtsIT 2017, DLI 2017. Lecture Notes of the Institute for Computer Sciences, Social Informati*, 2018, no. 229.
[22] C. N. D. Amorim *et al.*, Literature review of user needs, toward user requirements, 2020.
[23] B. Matusiak *et al.*, Subtask A : User perspective and requirements A.2 Use cases, 2021.
[24] C. Carpino, D. Mora, M. De Simone, On the use of questionnaire in residential buildings. A review of collected data, methodologies and objectives, Energy Build. 186 (2019) 297–318.
[25] K. Soini and A. Pirinen, Workshops – Collaborative Arena for Generative Research, in: *Proceedings of Designing Pleasurable Products and Interfaces*, 2005, pp. 1–17.
[26] N.G. Vasquez et al., Lighting conditions in home office and occupant's perception: Exploring drivers of satisfaction, Energy Build. 261 (2022) 111977.
[27] C.N.D. Amorim et al., Lighting conditions in home office and occupant's perception: An international study, Energy Build. 261 (2022).
[28] A. Koscher, S. Dittenberger, Setting the scene: A new proposal for visualizing and establishing 3-dimensional personas as a management tool, Proc. Int. Des. Conf. Des. 5 (2018) 2263–2274.
[29] T. Miaskiewicz, K.A. Kozar, Personas and user-centered design: How can personas benefit product design processes?, Des Stud. 32 (5) (2011) 417–430.
[30] F. Tang, L. Zeng, F. Wang, J. Zhou, Persona Authentication through Generative Dialogue, Comput. Lang. (2021) 12949.
[31] A. Cooper, The Inmates are Running the Asylum, Sams Publishing, Indianapolis, 2004.
[32] T. Adlin, J. Pruitt, The Essential Persona Lifecycle Your Guide to Building and, Elsevier, Morgan Kaufmann, 2010.
[33] L. Nielsen, From user to character – an investigation into user-descriptions in scenarios, in: *DIS2002 Conference Proceedings*, 2002.
[34] M.A. Blythe, P.C. Wright, Pastiche scenarios: Fiction as a resource for user centred design, Interact. Comput. 18 (2006) 1139–1164.
[35] M. Pérez-Montoro, L. Codina, Designing user experience, in: *Navigation Design and SEO for Content-Intensive Websites*, 1st Ed., 2017, pp. 65–84.